Table VIII.

Source of Mature Rats (over 90 grm.).	Source of Immature Rats (90 grms. or less).	Coefficient of Correlation.*
March data	March data	$-0\cdot23\pm0\cdot04$
April ,,	April ,,	$-0\cdot70\pm0\cdot02$
May ,,	May ,,	$-0\cdot81\pm0\cdot01$
April ,,	May ,,	$-0\cdot76\pm0\cdot02$
March ,,	May ,,	$-0\cdot69\pm0\cdot02$
March ,,	April ,,	$-0\cdot62\pm0\cdot02$

* The coefficients were determined by means of Pearson's approximate method ('Phil. Trans.,' A, vol. 195, p. 16, equation lvii) and the probable error assumed to be $3[0\cdot67449(1-r^2)/\sqrt{n}]$.

The Conduction of the Pulse Wave and the Measurement of Arterial Pressure.

By Leonard Hill, F.R.S., James McQueen, and Martin Flack.*

(Received December 20, 1913,—Read February 5, 1914.)

(From the Physiological Laboratory, London Hospital Medical College, London Hospital Research Fund; and the Pathological Laboratory, Aberdeen University.)

It is now well established that in cases of aortic regurgitation placed in the horizontal position the arterial pressure is considerably higher (50–80 mm. Hg) in the leg than in the arm.† Such pressures are taken by the sphygmomanometer, using the armlet method, the armlet being placed respectively round the calf and the upper arm, the disappearance and reappearance of the pulse wave being noted in the dorsalis pedis or posterior tibial artery, and in the radial.

In seeking for an explanation of this phenomenon it has already been suggested by us‡ that the "lability" of the arterial wall plays a considerable part, the term "lability" being used to designate the ease with which an artery distends with a rise and recoils with a fall of arterial pressure. The effect of increased and of diminished lability of the vessel wall upon the conduction of the pulse wave has been demonstrated schematically by

* During tenure of Eliza Ann Alston Research Scholarship.

† Hill, Flack, and Holtzmann, 'Heart,' vol. 1, p. 73 (1909); also Hill and Rowlands, 'Heart,' vol. 3, p. 222 (1912).

‡ Hill and Flack, 'Roy. Soc. Proc.,' B, vol. 86, p. 365.

Russell Wells* on rubber tubing made with a thickness of wall corresponding to an artery. While the lability effect has been shown by us in exposed arteries, in the body the main arteries are surrounded with tissues permeated with small arteries into which the blood pulsates. As the arterial wall is supported by the pulsing tissues the lability effects obtained on the exposed arteries cannot be directly ascribed to the same arteries *in situ.* Further investigation must be made on these.

Now J. McQueen, Ingram, and Leonard Hill† have shown that there is an extraordinary difference in the pressure required to damp down the pulse wave in arteries such as the aberrant radial and the dorsalis pedis, where these run superficially and lie upon bone, as compared with the same or other arteries lying in the midst of pulsating "resonating" tissues. They suggest that the pulse wave is supported on its way to the periphery by the pulsing tissues, and that the higher leg readings obtained in cases of aortic regurgitation may be due in part to the better conduction of waves which have a high crest through the pulsating mass of the abdomen and thigh. The reading of pressure in the case of the aberrant radial or dorsalis is taken with the Leonard Hill pocket sphygmometer. The small bag of this instrument when pressed on the radial artery (embedded in the tissues of the forearm) gives the same readings as the armlet method. When pressed on the aberrant radial or on the dorsalis pedis a far lower reading is obtained, *e.g.*, in a youth 35 mm. Hg against 110 mm. Hg.

We have constructed a wooden C-shaped box in which the arm can be suspended freely by a sling. If the armlet be placed round this box so that it presses on the front of the forearm, the obliteration of the pulse in the radial is obtained by the same pressure as is required if the armlet be used in the ordinary way. If the forearm be put in the box with the radial border uppermost, and the aberrant radial be pressed upon by the armlet, then the pulse is obliterated by a pressure of 35 mm. Hg. Using the armlet in the usual way the pulse is obliterated in this artery by 110 mm. Hg. In the one case the artery lying on bone is deformed by the armlet just as it is deformed by the bag. In the other case the pulse in the aberrant radial is not obliterated until the systolic pressure in the tissues of the forearm is overcome.

We have recently investigated several cases of "high blood-pressure" and find the following divergence between the readings of the leg and arm arteries, using the armlet and the dorsalis pedis, the patients being in the horizontal posture :—

* Russell Wells and Leonard Hill, 'Roy. Soc. Proc.,' B, vol. 86, p. 180.

† J. McQueen, Ingram, and Leonard Hill, 'Roy. Soc. Proc.,' B, vol. 87, p. 255 (1913).

	Arm, armlet.	Leg, armlet.	Dorsalis, L.H. small instrument.	Remarks.
	mm. Hg.	mm. Hg.	mm. Hg.	
G	225	275	139	Myocardial failure.
G′	250	295	130 (Temporal 135)	" " (aortic regurgitation found *post mortem*).
R	215	260	130	Myocardial failure.
C	185	255	100	" "
H	130	215	45	Aortic regurgitation.
M 1	180	175	65	Chronic nephritis.
M 2	170	175	55	" "
C 1	105	175	80	Mesaortitis.

In a normal individual we have found also that the variation in pressure found on changing from the horizontal to the vertical position fully accords with the effect of gravity, and that this is so when the readings are taken from the dorsalis pedis or with the armlet round the leg. The dorsalis reading in the vertical posture is increased by the gravity pressure just as much as is the leg reading.

The divergence in readings between the artery lying in tissues or exposed lying on bone has been fully substantiated by us in animals. If we place round the neck of a dog an armlet connected with a recording manometer and at the same time record the blood-pressure in the carotid artery by a v. Basch C-spring manometer, we find that the pressure required to obliterate the pulse wave on the tracing of the C-spring is just about the same as the actual systolic blood-pressure. To graduate the C-spring we

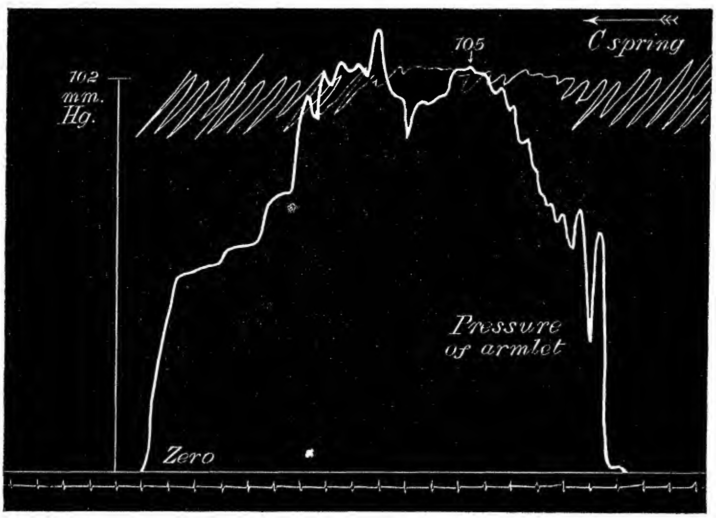

Fig. 1.

connect it with the Hg manometer and force up the pressure till the writer of the C-spring reaches the crest of the pulse curve (fig. 1).

We obtain similar results on applying to the carotid artery (*in situ*) of the cat the bag of the small Leonard Hill instrument instead of the armlet.

On the other hand, if we place a long length of the exposed carotid artery on the convex surface of a watch-glass, we find that the pulse wave is obliterated by a pressure in the bag much less than before. For example, in a dog with an arterial pressure of 190 mm. Hg. it was found that with the armlet 190 mm. pressure was required; in the same animal with the artery exposed but 60 mm. Hg. was required. In a cat we found—

The systolic pressure was..............	65	mm. Hg.	
And with the artery unexposed	64	„	was necessary to damp down pulse.
Artery lying exposed on muscles ...	26	„	„ „
Artery lying on scalpel handle (*cf.* fig. 2B).	12	„	„ „

To elucidate the cause of this marked difference in readings we devised the following experiment:—A long length of cat's carotid was exposed, the uppermost part ligated and divided. This end was first passed through a T-piece and then an arterial cannula inserted into it, which in its turn was connected with the C-spring manometer. As the artery passed in and out of the T-tube through a piece of rubber tubing, the latter could be constricted

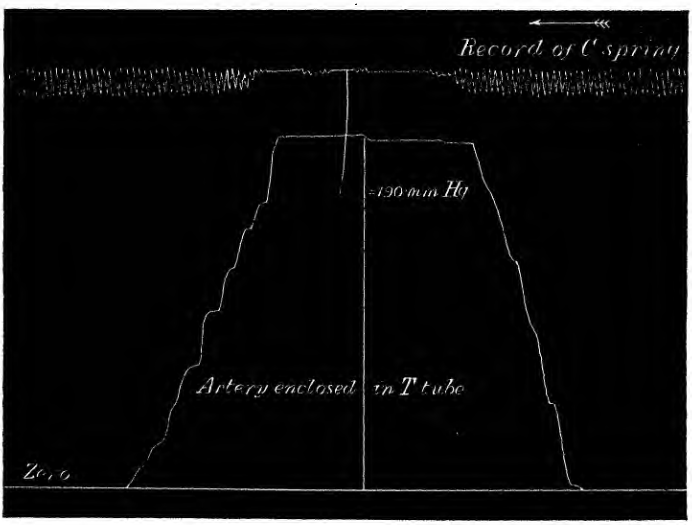

Fig. 2A.

Fig. 2B.

so as to prevent any considerable leak of fluid from the T-tube. The artery in the T-tube was then surrounded by Ringer's solution and the pressure of this raised. Obliteration of the pulse wave occurred when the pressure in the T-tube reached that in the artery—190 mm. Hg. (fig. 2A). The same exposed artery removed from the T-tube and placed across the dome of a watch-glass required but 27 mm. Hg (fig 2B).

This experiment demonstrates the fact that the deformation of the arterial lumen is the prime cause of the obliteration of the pulse wave. When the artery is circularly and equally compressed by surrounding fluid, the pulse continues to come through until the full systolic pressure is overcome. In the case of the artery exposed and lying on a rigid surface, when the bag is pressed on it the arterial wall is pushed in above and bulged out at the sides. The lumen is thus converted from a circle into an ellipse, and resistance is offered to the pulse by the changed shape. The force of the pulse is spent on the labile wall of the artery in front of this resistance.

In corroboration of this experiment we have also found that if the finger be gently laid along the course of the radial artery and the bag of the sphygmomanometer pressed upon the finger until the pulse ceases to come through under it, a less pressure is required than without such interposition of the finger. This is because the finger brings about the deformation of the artery more easily than the bag. If the armlet be used and the finger be inserted under the armlet to palpate the artery, one finds that the pulse does not cease to come through under the finger until the full systolic pressure is reached. Thus the readings were 35 and 97 mm. Hg respectively in the case of a youth.

In the aberrant radial artery the pulse was obliterated by 55–60 using the bag, by 35 using finger and bag. Using armlet and finger the radial was obliterated by 135 and using armlet alone by 135.

A thin, distensible rubber bag inflated with a pressure of air can easily be deformed from the spherical to elliptical or other shape without altering the internal pressure. The bag may thus be made to take a shape which would give great resistance to the passage of a pulse wave or flow of fluid, although the total volume and pressure of the air in the bag remains unaltered.

In the experiments on animals (goat, dog, cat) it was found that the pressure required to obliterate the pulse wave in the exposed artery varied from 25 to 60 mm. Hg. To elucidate the cause of the higher and lower readings we measured the pressure necessary for the obliteration of the pulse in the same exposed artery with the animal (cat) in the head-down, horizontal, and feet-down position. We found that the pressure necessary

to obliterate the pulse varied markedly with the diastolic pressure within the artery:—

	Diastolic pressure.	Obliteration pressure.
	mm. Hg.	mm. Hg.
Head-down.........	160	48
Horizontal	134	28
Feet-down	125	20

The lability of the wall also plays a part, since with the same diastolic pressure a higher pressure is required to obliterate the pulse in the carotid artery of the dog or goat than in that of the cat.

McQueen, Ingram, and Leonard Hill found that when the pulse in the aberrant radial artery was obliterated by a pressure in the bag of, say, 45 mm. Hg, the blood still trickled slowly into the artery. We have made a cut into the exposed carotid of a cat and found that a pressure of 26 mm. Hg stopped the visible flow; a pressure of 20 mm. Hg allowed slow oozing from a very elliptical lumen; while a pressure of 10 mm. Hg allowed the blood to spout freely through the incision.

In the above investigations the remarkable fact comes out that the pressure required to deform the artery and to obliterate the pulse wave is considerably below even the internal diastolic pressure of the vessel. To investigate this phenomenon further, we compared the effect of perfusing, with the same pulsating head of pressure, thin rubber tubing (about 0·7 mm. thick) and a length of human artery of approximately the same calibre and thickness of wall, and noting the external pressure required to obliterate the pulse wave The results are as follows:—

	Systolic pressure.	Obliteration of pulse, pressure in bag.
	mm. Hg.	mm. Hg.
Rubber	140	195 (fig. 3)
Artery	130	46 (fig. 4)

The rubber tube resisted deformation, the labile arterial wall suffered deformation easily.

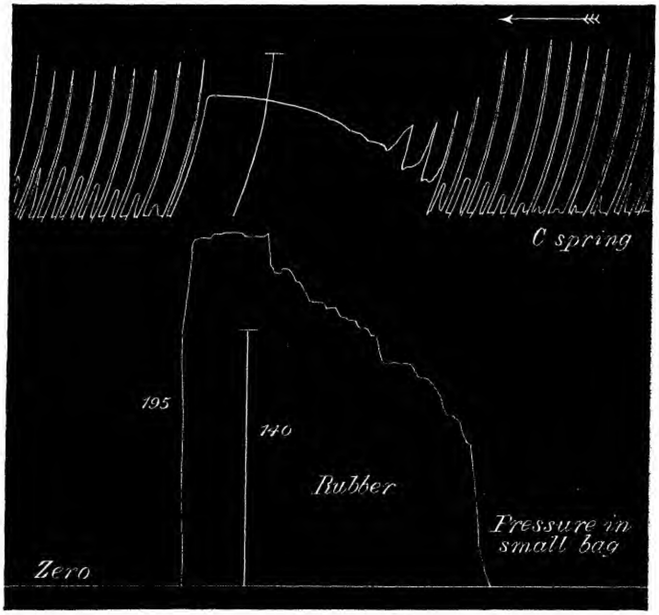

Fig. 3.

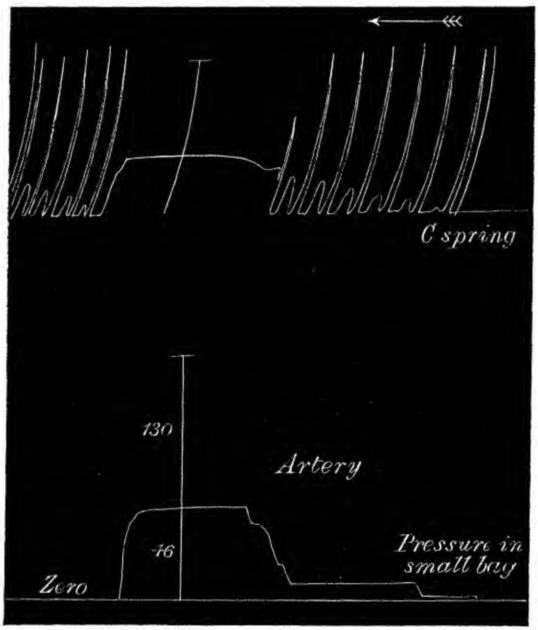

Fig. 4.

We then immersed a piece of the same rubber tubing in xylol. The tubing quickly imbibed xylol and became swollen, less elastic, and more easily

distended or deformed. Experimenting in the same manner with this xylol-soaked tube we obtained—

Systolic pressure.	Obliteration pressure.
mm. Hg. 133	mm. Hg. 95 (fig. 5)

Thus the rubber tube by soaking in xylol was brought to resemble the artery.

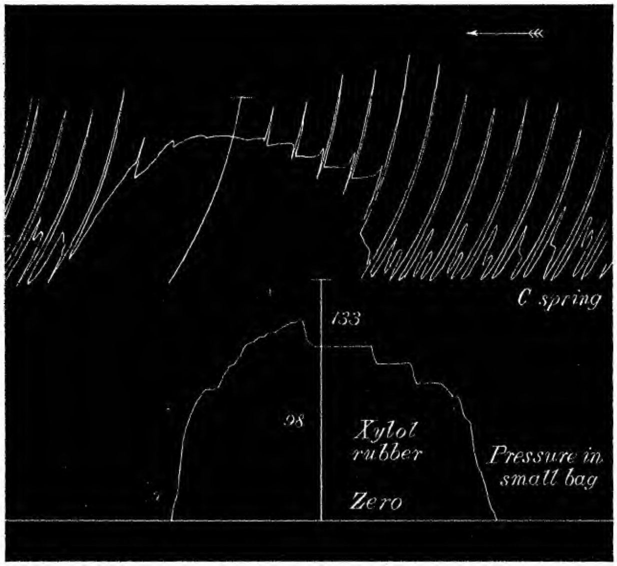

Fig. 5.

Further experiments we have done on human arteries are these:—

I. We bandage the arm with a rubber bandage, place the armlet on the upper arm, raise the pressure in it above systolic pressure, and then remove the bandage—the arm is left exsanguined. We now place the sphygmograph (using the weight extension method) in position on the radial artery, then let go the armlet. We find that the pulse curve returns slowly to its full amplitude when the weight extension is 300 grm., while it returns almost instantaneously when the weight is 150 grm. (see fig. 6, 2 and 3). When the heavier weight is used the pulse wave does not lift it until the tissues fill with blood and the peripheral resistance increases to such a degree that the systolic pressure in the surrounding tissues and artery overcomes the pressure of the sphygmograph pad which is pressing

upon them. If the arm be not exsanguined the pulse returns at once to its full amplitude in spite of the heavier extension weight (fig. 6, 1).

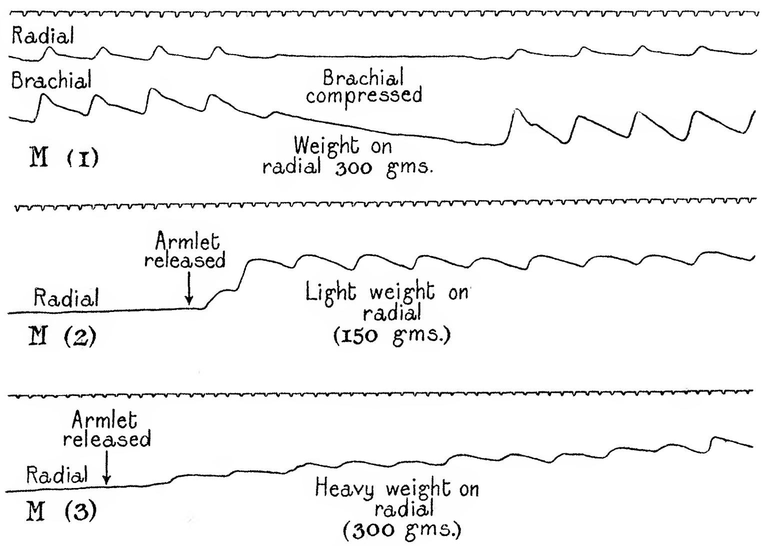

Fig. 6.

II. We surround the upper arm with ice, while the lower arm is immersed in hot water. After a few minutes the obliteration pressure is taken with the armlet on the flushed forearm, while the upper arm is still encased in ice. Under these circumstances we have generally found that the pressure in the lower arm is 15–20 mm. Hg higher than it was before the experiment. The ice is then removed from the upper arm and the pressure quickly taken with the armlet there. In this case the pressure is generally slightly lower

	Before experiment, armlet round either upper arm or forearm.	Armlet round flushed forearm, upper arm cold.	Armlet round upper arm, ice just removed.
	mm. Hg.	mm. Hg.	mm. Hg.
G. S.	97	120	95
G. S.	97–100	120	95
J. McQ.	130	142	125
M. F.	115	125	112
M. F.	105	105	85–88
	—	95	90–95
		(Other arm, 105)	(15 minutes later)
S. E.	105–108	115	103–105
		—	97
			(5 minutes later)
		105 After application of ice to forearm	

(3–5 mm. Hg) than at the beginning of the experiment. In one case, when the application of the ice had been so long that the skin of the arm had become red in patches, the pressure in the upper arm was lowered 20 mm. Hg.

It is a remarkable fact that the readings obtained from the cold upper arm should be lower than those obtained from the flushed forearm.

The tentative explanation we offer of these results is as follows. The vessels in the tissues of the upper arm under the influence of the ice are constricted and largely exsanguined, thus the artery is less well supported by the resonance of the pulse in these tissues, and is therefore deformed by a lower pressure than is required in the flushed forearm, where the resonance of the systolic wave is greater. At the same time the cold contracted artery in the forearm conducts the crest of the wave better to the flushed forearm since it is less labile. The readings obtained from the cold upper arm show that the wall of the artery, even though contracted by cold, does not offer such a resistance to compression as to influence the readings. We (L. H. and M. F.) reached the same conclusion by methods we devised for testing the readings we obtained in cases of high blood-pressure.*

Conclusions.

We conclude that the armlet or Leonard Hill's small bag, applied to the radial artery, give, under ordinary conditions, accurate readings of systolic pressure, the obliteration of the pulse being taken as the index. This is because the artery is surrounded by pulsing tissues and cannot be deformed until the systolic pressure is overcome in these tissues. The artery is equally compressed on all sides by a pulsating fluid pressure and the conditions are the same as when it is compressed in a glass T filled with Ringer's fluid. In the dorsalis pedis, the temporal, or aberrant radial artery, where lying on bone and tendon, the pulse is obliterated by a pressure of the small bag much lower than the systolic pressure. This is because the lumen of the labile arterial wall is deformed more easily under these conditions from the circular to an elliptical shape, and the resistance to the passage of the pulse wave thereby increased.

The higher the diastolic pressure the greater must be the pressure of the bag to produce the required deformation. As the amplitude of the pulse wave depends so much on the size of the lumen, it seems probable that the higher readings obtained in cases of aortic regurgitation are due in part to the lumen of the aorta, iliac and femoral arteries being relatively wider than that of the subclavian and brachial arteries. The pulsating (resonating) support given to the former arteries by the relatively massive abdominal organs and

* 'Brit. Med. Journ.,' January 30, 1909.

the tissues of the thigh may also help to prevent the damping of the crest of the pulse waves. The leg arteries are probably held in a more supported state, less labile, and for this reason also the pulse will be conducted to the leg with less diminution in force. Size of lumen, resonance and lability are three factors which may all take a part in the production of this phenomenon. We have brought forward in this paper experiments which demonstrate these factors at work.

This research was carried out with the aid of a grant from the Royal Society Government Grant.

On the Floral Mechanism of Welwitschia mirabilis, *Hooker.*

By Arthur Harry Church, Lecturer in Botany, University of Oxford.

(Communicated by Prof. A. C. Seward, F.R.S. Received December 23, 1913,—Read February 5, 1914.)

(Abstract.)

1. In the preparation of sectional schemes for the flowers of *Welwitschia mirabilis*, in different stages of development, several points of interest were noted as tending to throw light on the previous history of this unique floral form.

2. Evidence is adduced to show that the primary structural features of the flowers are referable to an anthostrobiloid condition closely comparable with that of *Cycadeoidea*, now expressed in a phase of minimum reduction, and to be regarded as an example of heterophyletic convergence to a simple floral construction in the gymnospermic condition.

3. Secondary features of biological interest are mainly consequences of xerophytic specialisation in the inflorescence; condensation of the whole system to a "cone" necessitates the extreme flattening of the flower in the transverse plane, which has led to confusion in the interpretation of the facts of development; the andrœcium is represented by a true whorl of six members.

4. Similarly, secondary clisanthy in the cone mechanism necessitates special features in the individual flowers, and accounts for the long exserted micropylar tube of the ovulate flower, and the protrusion mechanism of the staminal tube in the sterile flower.